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The energy and environmental impacts of Italian households consumptions: An input–output approach

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ABSTRACT

Promoting sustainable consumption and production patterns is a key challenge for the future, in order to use the Earth resources efficiently, to reduce the greenhouse gas emissions, and to decouple the economic growth from the environmental degradation.

New or customized methods have to be applied to support decisions makers in the choice of environmental-friendly products, and to select policy priorities and sustainable strategies.

A modified input–output model can aid to analyse the relationships among economic growth, energy consumptions and pollutants, in order to assess the energy and environmental impacts due to the actual production and consumption patterns.

The following paper introduces an energy and environmental extended input–output model and combines it with the Life Cycle Assessment (LCA) methodology.

The authors apply this model to the Italian context in order to assess the energy and environmental impacts related to the consumptions of the Italian households in the period 1999–2006 and to identify the economic sectors involving the highest impacts.

The paper represents one of the first Italian studies aimed at identifying those national economic sectors and final goods and services to be assumed prior in the definition of sustainable production and consumption strategies. Results show that about the 70% of the total energy, needed to meet the household final demand of products, is consumed by the productive sectors. In particular tertiary, "electricity, gas and vapour", road transports and "food and beverage" sectors are the most contributors, accounting for about 75%.

Further, the environmental impact analysis associated to Italian households consumptions is carried out, starting from three different data sources The results point out that, to include emissions arising both from energy and non-energy sources, in the assessment of environmental impacts is of paramount importance to obtain reliable simulations of the link between households consumptions and energy and environmental performances.

Contents

1. Introduction . . . 3898
2. The energy and environmental input–output model . . . 3899
   2.1. The input–output model . . . 3899
   2.2. The IOA extended to energy and environmental contest . . . 3900
3. Data source . . . 3900
4. Main results of the study . . . 3901
   4.1. Energy results . . . 3902
   4.2. Environmental results . . . 3902
5. Conclusion . . . 3906
   Appendix A . . . 3907
   Appendix B . . . 3908
   References . . . 3908

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Nomenclature

Acronyms

AP	Acidification Potential
COICOP	Classification of Individual Consumption by Purpose
CPA	Classification of Product by Activities
EEIO	Environmentally Extended Input–Output
EP	Eutrophication Potential
GWP	Global Warming Potential
IO	Input–Output
IOA	Input–Output Analysis
IOTs	Symmetric input–output tables
ISTAT	Italian Statistical Office
LCA	Life Cycle Assessment
NACE	General Industrial Classification of Economic Activities within the European Communities
NAMEA	National Accounting Matrix including Environmental Accounts
POCP	Photochemical Oxidation
SUTs	Supply and Use Tables

Symbols

A	matrix of technological coefficients
E	matrix of energy consumption per unit of output
E_{dir}	vector of direct energy consumptions
E_{ind}	matrix of indirect energy consumptions
F	matrix of emission factors related to energy use
F_{dir}	vector of direct air emissions related to energy use
F_{ind}	matrix of indirect air emissions related to energy use
F_{LCA}	matrix of emission factors related to energy “life-cycle”
F_{LCAdir}	vector of direct air emissions related to energy “life-cycle”
F_{LCAind}	matrix of indirect air emissions related to energy “life-cycle”
G	matrix of characterization factors
I	identity matrix
$(I-A)^{-1}$	Leontief inverse matrix
I_{dir}	vector of direct environmental impacts
I_{ind}	matrix of indirect environmental impacts
$I_{t,t\text{-}1}$	index that represents the ratio between the prices for the years $t-1$ and t
$I_{t+1,t}$	index that represents the ratio between the prices for the years t and $t+1$
P	matrix of air emissions per unit of output
P_{dir}	vector of direct air emissions
P_{ind}	matrix of indirect air emissions
$v_{i,t(t-1)}$	element of the SUTs referred to the year t and expressed at prices of the year $t\text{-}1$
$v_{i,t(t)}$	element of the SUTs referred to the year t and expressed at prices of the year t
$v_{i,t+1(t-1)}$	element of the SUTs referred to the year $t+1$ and expressed at prices of the year $t-1$
$v_{i,t+1(t)}$	element of the SUTs referred to the year $t+1$ and expressed at prices of the year t
$v_{i,t+1(t+1)}$	element of the SUTs referred to the year $t+1$ and expressed at prices of the year $t+1$
X	vector of the total outputs
Y	vector of the final demand

1. Introduction

The current production and consumption patterns represent a serious threat for the quality of life and the well-being of present and future generations.

In 2006 US$24 trillion were spent to meet the households demand of goods and services in the world, compared to US$4.8 trillion in 1960 [1].

The increase of the population, which is forecast for 2050 (9 billion compared to the current 6.8 billion), will bring about 2 billion of new consumers to join to the global middle class by 2030, conveying almost 80% of the world's global Gross Domestic Product (GDP) into a “consumer” bracket [2,3].

The increasing consumptions, mainly due to the population growth and to the continuous changes of lifestyles in many parts of the world, cause the overexploitation of natural resources, the degradation of natural habitats, and the release of huge amounts of pollutants, that are irreparably damaging ecosystems and overcoming the environmental carrying capacity.

The increase of consumptions also substantially nullifies the improvement that the technological innovation and the growth of the energy efficiency have brought in the environmental performances of products. Consumers play a key role in moving toward more sustainable consumption patterns by the choices and decisions that they make. They should be encouraged to behave more sustainably without lowering their life quality [4,5].

Fundamental changes in the production and consumption patterns, to promote social and economic development within the carrying capacity of ecosystems [6], can be get by means of the following sustainable strategies [7,8]:

- to introduce actions of greening production, as the reduction of the impact intensity of mining and manufacturing activities, the implementation of end-of-pipe measures and structural technical changes in production processes;
- to promote the consumption of low impact products and services;
- to increase the eco-efficiency of products by decreasing material and energy use per functional unit;
- to reduce volumes of consumption, while maintaining life quality;
- to introduce incentives and rules to address consumption and production patterns toward sustainability.

To meet these challenges, new or customized tools and methods should be defined to assess energy and environmental burdens of goods and services and to identify the products with the highest potential of improvement, so that decision makers are allowed to define policy priorities and put into practice strategies of sustainable development [9,10].

Currently, the most applied methods to assess the energy and environmental impacts of goods and services are the following [7,11]:

- the Life Cycle Assessment (LCA), which is aimed at analysing the impacts from cradle to grave of a product or a service;
- the Environmentally Extended Input–Output (EEIO) analysis, usually applied to assess the impacts of a whole economy combining economic and environmental data.

On one hand, the LCA methodology allows to obtain detailed information on the life cycle of a single product, but it should require too much data and excessive time and money consumption if it was applied to assess the environmental impacts of a whole economy. On the other hand, EEIO analysis provides rather highly aggregated results, but it uses public data and it is fast and low cost to be performed, compared to LCA.

Since the 1970s many authors have used the Input–Output Analysis (IOA) to develop studies related to environmental issues (energy consumptions, water and land use, pollution, waste production, etc.) [12] and to support information-based environmental and economic policies [13].

The IOA is used nowadays intensively in the context of environmental economics, environmental LCAs, scenario and policy studies, embodied pollution of trade, and similar subjects that relate to sustainable production and consumption. Literature presents many studies of EEIO analysis.

Gowdy and Miller [14] used input–output tables to study the effects of technological changes and demand trend on the energy use in the United States from 1963 to 1977; Han and Lakshmanan [15] examined the effects of structural changes of the Japanese economy on the energy intensity in the period 1975–1985; Alcantara and Roca [16] analysed the primary energy demand and the CO_2 emissions in Spain from 1980 to 1990; Lenzen [17] studied the flows of energy and greenhouse gases in the Australian economy; Cruz [18,19] assessed the energy consumption and the CO_2 emissions in Portugal; Mongelli et al. [20,21] analysed the short-term effects of a carbon tax in Italy; Nijdam and Wilting [22] developed a method based on the IOA to calculate the direct and indirect environmental impacts related to the households consumptions in Holland; Ardente et al. [23] applied the IOA model to carry out the energy and environmental analysis of the Sicilian context, highlighting that such a model can be used to monitor the trend of greenhouse gas emissions, to evaluate the sectors responsible of the largest impacts and to state the efficacy and efficiency of the regional energy and environmental policies.

Since the 1990s, IOA was also used as "hybrid" model to support LCA studies [24,25]. Hendrickson et al. [26] developed a method, called Economic Input–Output Life Cycle Assessment (EIO-LCA), that combines economic and environmental data. Tukker et al. [11], within the EIPRO (Environmental Impact of Products) European project, developed a methodology based on the IO structure and integrated it with physical data regarding to the use phase and end-of-life of products and services, in order to identify the European products characterized by the highest life-cycle environmental impacts [27,28].

Another European project was "EXIOPOL"[1] with the following goals: (1) to estimate the external costs of a broad set of economic activities for Europe; (2) to set up a detailed EEIO framework, linked to other socio-economic models; (3) to assess the environmental impacts and external costs of different economic activities, final consumption activities and resource consumption for countries in the EU.

The following sections present an energy and environmental IO model combined with LCA. The model is applied to the Italian context for the period 1999–2006, in order to analyse the impacts arisen from the Italian household consumptions and to identify the most impacting products and services.

The original contribution of this study is twofold. First, from a methodological point of view, an energy and environmental extension of the IO model is combined with the LCA and shaped to the available economic, energy and environmental data for Italy. Then, from a decisional point of view, the model provides a useful set of energy and environmental outcomes to identify the "priority areas" on which the next Italian policies and strategies must be addressed.

In Section 2 the model is described in detail. In Section 3 data sets and procedures of data processing used in the study are shown. Section 4 contains the main results of the study, while Section 5 provides some final remarks.

[1] http://www.feem-project.net/exiopol/index.php.

2. The energy and environmental input–output model

2.1. The input–output model

The IOA, which was originally developed by Wassily Leontief, shows the economic interrelations among productive sectors and between these and the final consumers.

Such a method is based on the following main equation [29–31]:

$$X = (I - A)^{-1} Y \tag{1}$$

where Y is the vector of the final demand of goods and services, X is the vector of the total outputs needed to satisfy the final demand, I is the identity matrix and A is the matrix of technological coefficients.[2]

The inverse matrix $(I-A)^{-1}$ is known as "Leontief inverse matrix".

Note the matrix A, Eq. (1) allows to assess the total output X of all the economic sectors needed to satisfy a specific final demand Y.

The coefficients of the Leontief inverse matrix indicate the impact of a unit change in the exogenous final demand on the output of the industry. The importance of each coefficient is that it captures both direct and indirect effects arising from the interdependence of all industries in the production of goods and services to meet the final demand [32].

As a forecasting tool, Eq. (1) is an appealing and easy to use formula. The reliability of the forecast depends on the accuracy both of the final demand vector and of the Leontief inverse matrix.

The use of the IOA involves some assumptions summarized in the following [23,33,34]:

- Constant returns of scale: the same relative mix of inputs is used by an industry to produce output, independently to the produced quantity. It implies:
  - Constant technological coefficients: the amount of input necessary to produce one unit of output is assumed to be constant in the short term, regardless to price effects, changes in technology or economies of scale.
  - Linear production functions: the IO process assumes that if the output level of an industry changes, the input requirements will change proportionally.
- It is supposed that each economic sector produces and sells one and only one homogeneous good.
- There are no resource constraints. Supply is assumed infinite and perfectly elastic.
- Local resources are efficiently employed. There is no underemployment of resources.
- IO tables describe an economy in a specific period; they do not highlight the trend of the economic interrelationship in the long time.

Despite the above assumptions, the IOA represents a valid method to provide a reliable description of an economy in the short time.

The economic data needed for the application of the IOA are showed in the symmetric IO table (IOT), which is obtained combining the information contained in the Supply and Use Tables (SUTs).

An IOT describes the interconnections among sectors of economy for any given period. Each row describes the amount of output of each sector that is distributed to other sectors and/or to final

[2] The technological coefficient a_{ij} represents the amount of product generated by the industry i used to generate one unit of product of the industry j.

users; each column indicates the amount of inputs required to produce the total output of the corresponding sector.

A supply table shows the origin of the resources for goods and services, while the use table shows the use of those goods and services and the cost structure for the various industries.

As a statistical tool, SUTs provide a coordinating framework for checking the consistency of economic statistics on flows of goods and services obtained from the different kind of statistical sources. As an analytical tool, the tables are conveniently integrated into macroeconomic models in order to analyse the links and interactions between final demand and industrial output levels [35].

2.2. The IOA extended to energy and environmental contest

The IOA, opportunely combined with energy and environmental data, can assess the direct and indirect energy consumptions and pollutant emissions arisen from goods and services needed to meet the final demand of consumers.

In the following, an energy and EEIO model, customized to the Italian contest, is presented. The model was elaborated starting from [18,19,36].

Let suppose to have an economic system constituted by n sectors that use m energy sources, as fossil fuels, electricity, biomasses, etc., which will be indicated as “energy” in the following sections.

The energy consumed by the economic system is considered as the sum of the indirect energy used by productive sectors to produce goods and services, and the direct energy consumed by the final users.

The indirect energy is expressed with a $(m \times n)$ matrix $E_{ind,}$ whose generic element $e_{ind,ij}$ represents the physical amount of energy i used by the productive sector j to generate the total monetary output:

$$E_{ind} = EX = E(I - A)^{-1}Y \tag{2}$$

where E is a $(m \times n)$ matrix, whose generic element e_{ij} represents the physical amount of energy i involved in the productive sector j to generate one monetary unit of output.

The direct energy consumption is expressed with a vector E_{dir}, whose generic element $e_{dir,i}$ represents the physical amount of energy i employed by final users.

With regard to the pollutant emissions, they can be obtained as the sum of the indirect emissions arising from productive sectors and the direct emissions caused by final consumers.

The indirect emissions associated to a specific final demand Y can be expressed by a $(r \times n)$ matrix P_{ind}, whose generic element $p_{ind,kj}$ represents the amount of pollutant k produced by the economic sector j to generate the total monetary output:

$$P_{ind} = PX = P(I - A)^{-1}Y \tag{3}$$

where P is a $(r \times n)$ matrix, whose elements are the emission factors of r pollutants generated by each sector to produce a monetary unit of output.

The direct emissions can be expressed by a vector P_{dir}, whose generic element $p_{dir,k}$ represents the amount of pollutant k directly emitted by the final users.

If any information to build the matrix P is available, it is possible to estimate the emissions due only to the direct and indirect energy used to meet the final demand of goods and services.

Multiplying a $(r \times m)$ matrix F, whose generic element f_{ki} represents the emission of pollutant k arising from the use of one physical quantity of energy i, for the matrix E_{ind} defined in Eq. (2), a matrix F_{ind} is obtained, that represents the quantity of pollutants caused by the total energy use:

$$F_{ind} = FE_{ind} = FE(I - A)^{-1}Y \tag{4}$$

The direct emissions arising from the direct energy use are expressed by the vector F_{dir}:

$$F_{dir} = FE_{dir} \tag{5}$$

Let's define F_{LCA} as a matrix whose generic element $f_{LCA,ki}$ represents the amount of pollutant k arising from the life cycle of one physical amount of energy i. Substituting it to F, it is possible to assess the emissions related to the indirect and direct energy consumptions needed to meet the final demand of goods and services following a life cycle approach:

$$F_{LCAdir} = FE_{dir} \tag{6}$$

$$F_{LCAind} = F_{LCA}E_{ind} = F_{LCA}E(I - A)^{-1}Y \tag{7}$$

Eq. (6) takes into account only the emissions arising from the energy use step, while the emissions related to the energy production, or the indirect energy, are accounted for in the matrix F_{LCAind}.

Defined a $(r \times s)$ matrix G of the characterization factors per impact category, whose generic element g_{kx} represents the contribution of the pollutant k to the environmental impact x, the environmental impacts associated to the final user consumptions can be calculated as following:

- starting from the matrixes P_{ind} and P_{dir}:

$$I_{ind} = GP_{ind}; \quad I_{dir} = GP_{dir} \tag{8}$$

- starting from the matrixes F_{ind} and F_{dir}:

$$I_{ind} = GF_{ind}; \quad I_{dir} = GF_{dir} \tag{9}$$

- starting from the matrixes F_{LCAind} and F_{LCAdir}:

$$I_{ind} = GF_{LCAind}; \quad I_{dir} = GF_{LCAdir} \tag{10}$$

I_{ind} is a $(s \times n)$ matrix of the impacts generated by different economic sectors, while I_{dir} is a vector that expresses the impacts directly involved by the final users.

The model presents some limitations, mainly related to the basic assumptions of the IOA (constant technical coefficients and linearity of production function). The main simplification is that there is a linear correlation between the monetary production and the energy consumptions or pollutant emissions. The reliability of the results strictly depends on the quality of input data, that can be influenced by errors and sources of uncertainty as the following [26]:

- Errors in the data collection. The errors can be due to sampling of data, procedures of data collection, and to the assessment of incomplete or missing data.
- Missing of recent data. To apply the model, often are available old data that do not represent the real trend.
- Use of average economic, energy and environmental data to describe different products arising from the same sector.
- The model assumes that imported products are produced in the same way as the equivalents from the corresponding domestic industry. The uncertainty associated with the importations grows with the increase of the quantity of imported products.

3. Data source

The application of the energy and EEIO model to the Italian context requires economic, energy and environmental data provided by different sources.

Economic data, published by the Italian Statistical Office (ISTAT), are provided in the SUTs, that subdivide the economy in 59 economic sectors following the General Industrial Classification of Economic Activities within the European Communities (NACE), and 59 products following the Classification of Product by Activities

(CPA). These classifications are fully aligned to each other. At each level of aggregation, the CPA shows the principal products of the industries according to the NACE [37,38].

According to EIPRO project, an interesting analysis should be made considering the Classification of Individual Consumption by Purpose (COICOP). Unfortunately, ISTAT does not publish the transition matrix that would allow to transform the classification of products from CPA to COICOP.

The Italian SUTs are available from 1999 to 2006 at basic prices[3] and in current monetary values, wherein the value of a transaction is equal to the price per unit of quantity in one year multiplied by the units involved in the transaction in the same year. This implies that when analyzing changes between different SUTs over years, the observed changes can be caused by variations in prices or in quantities [40].

To make easier the application of the IOA, SUTs should be compiled both at current prices and constant prices [41]. This implies that all values in such tables (economic transactions, outputs, taxes, intermediate and final employments, etc.) should be deflated at prices of a base year, using specific indices of price. A detail of the deflation methods of IOTs can be found in [38,42]. However the information needed to deflate the IOTs is often incomplete or not available. This is the case for Italy.

In order to avoid the influence of price variations on the final results, the authors defined a framework, described in detail in Appendix A, to estimate the SUTs in constant prices referred to year 1999 (base year).

Since the official Italian IOTs at prices of 1999 or of any base year are unknown, it must be highlighted that it is not possible to analyse how far are the estimated tables from the real ones.

The Italian IO tables at basic prices and in current monetary values are published by ISTAT every five years. In order to analyse the economic flows from 1999 to 2006, "product by product" IOTs at monetary values of 1999 were derived according to [37,38], starting from SUTs in constant prices of the base year (Appendix B).

The energy data are derived from the tables of the National Energy Balance published by the Department of the Economic Development,[4] and from the Energy and Environment Report published by ENEA.[5]

Environmental data related to the air emissions of nine pollutants are available in the National Accounting Matrix including Environmental Accounts (NAMEA), published by ISTAT from 1999 to 2006. Emission factors related to the use phase and the life-cycle of different energy sources are referred to Ecoinvent database [43].

The results of an IOA are as much detailed as more sectors are included. However, since different classifications are used for economic activities in the IOT (59 sectors of disaggregation) and in the energy tables (20 sectors of disaggregation), a single classification was defined. Starting from information provided by the Italian Department of Economic Development the economic activities was aggregated in 17 sectors (Table 1). Despite the loss of information, the aggregation of economic sectors was necessary in order to fit the size of economic matrix to the size of energy and environmental ones.

4. Main results of the study

In the examined period, some macroeconomic indicators show an increasing trend (Fig. 1). In detail, the Italian household consumptions increase of about 10%, the intermediate employments of 15.6% and the total resources or employments of 14.8%. Imports and exports grow to 30.4% and to 26.7% respectively.

Table 1
Classification of the economic activities.

Agriculture, hunting and forestry
Fishing
Mining
Food and beverages
Textile and clothing
Other manufacturing
Paper and graphics
Chemistry and petrochemical
Building materials, glass and ceramic
Metallurgy
Mechanics
Construction
Electricity, gas and vapour
Tertiary
Public Administration
Road transports
Sea freights
Air transports

Analysing the incidence of the different goods and services on the above indicators, it can be notice that:

- the products of tertiary sector represent the 62% of the final expenditures, followed by products of public administration (10%) and "food and beverage" (6%) sectors;
- the products of tertiary sector use 45% of the total intermediate employments, followed by products of metallurgy (8%), mechanics (7.5%) and "chemistry and petrochemical" (5%) sectors;
- the products of tertiary sector consume around 44% of the total resources or employments, followed by products of mechanics sector (11%). The products of the other sectors have an incidence on the total lower than 4–5%;
- the imports mainly concern the products of mechanics (32%), "chemistry and petrochemical" (13%), tertiary (13%) and metallurgy (8%) sectors;
- the exports mainly concerns the products of the mechanics (35%), tertiary (14%), "textile and clothing" (12%), other manufacturing (9%), "chemistry and petrochemical" (8%) and metallurgy (7%) sectors.

Starting from the IO tables and applying the IO model, the trend of the total output for each economic sector, needed to meet the final demand of households, is calculated for the period from 1999 to 2006. It results characterized by an increase of about 8%.

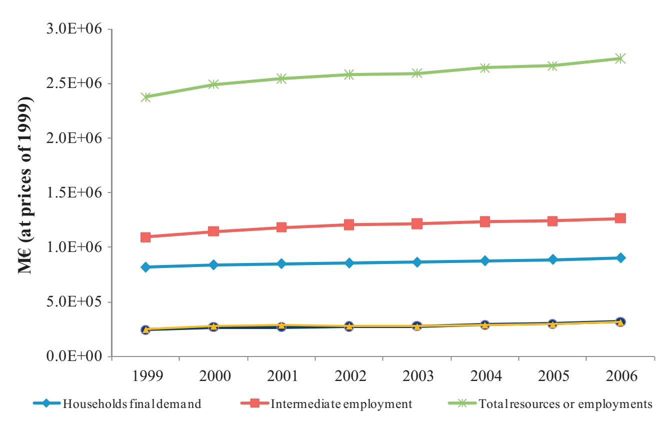

Fig. 1. Trend of some Italian economic indexes (1999–2006) (expressed at prices of 1999).

[3] The basic price is the amount receivable by the producer from the purchaser for a unit of good or service produced as output minus any tax payable, and plus any subsidy receivable on that unit as a consequence of its production or sale [39].

[4] http://dgerm.sviluppoeconomico.gov.it/dgerm/ben.asp.

[5] http://www.enea.it/produzione_scientifica/REA.html.

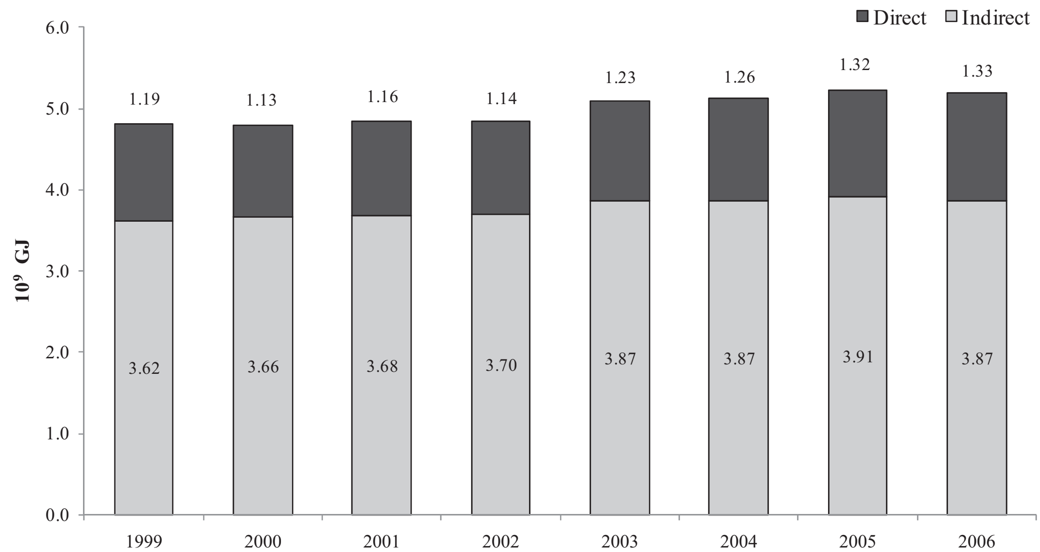

Fig. 2. Direct and indirect energy consumptions (1999–2006).

The economic sectors that mainly contribute to the total output production are: tertiary (56%), "food and beverage" (7%), mechanics (5.5%), "textile and clothing" (5%), "chemistry and petrochemical" (4.2%), road transports (4%), other manufacturing (3%), agriculture (3%). Each other sector gives a contribution lower than 2.5%.

As shown in Table 2, there is a general increase of the total output from 1999 to 2006, and almost all the sectors increase the production, except for fishing, "chemistry and petrochemical", metallurgy, public administration, sea freights and air transports.

The contribution of the different sectors to the total output do not have significant changes between 1999 and 2006.

4.1. Energy results

The direct and indirect energy consumptions, necessary to meet the Italian household final demand of goods and services, varies from 4.81×10^9 GJ in 1999 to 5.20×10^9 GJ in 2006 (Fig. 2). It can be noted that about 70% of the total energy consumption is due to the indirect use, of which 92% arises from the domestic production and only 8% arises from the imported products.[6]

Direct energy consumptions are showed in Fig. 3. Among the energy sources used by households, the main are natural gas, whose contribution on the total direct energy consumption grows from 53.5% to 59.5%, electricity, which increases from 20% to 28%, and gas oil which increases from 9% to 14%.

Specific energy consumptions from 1999 to 2006, expressed as MJ/inhabitant, are shown in Table 3. The increase of 3.2% in the population involves a variable trend of energy consumptions (direct, indirect and total).

The highest share on the indirect energy consumption comes from the products of tertiary sector (31%), followed by "electricity, gas and vapour" (19%), road transports (16%) and "food and beverage" (8.5%). The remaining groups of products share for less than 6% (Table 4).

Similar results are obtained by seven studies reviewed in the EIPRO project [11]. The review showed that even if a broad spectrum of approaches, methods and data sources are used, in each study the products with the highest energy and environmental impacts are those related to the "food and drink", transport and housing sectors.

Table 5 shows the different energy sources consumed in the examined period. The most used sources are: natural gas (from 26.5% to 32%), gasoil (from 15% to 18.7%), electricity (around 13%), gasoline (from 9% to 13%) and low sulphur fuel oil (from 7% to 10.5%).

Table 6 shows the energy use per unit of produced output in 1999–2006, in order to identify the sectors with the highest energy consumption and those ones with an improved efficiency in that period.

4.2. Environmental results

Table 7 shows the emissions associated to the Italian households consumptions, assessed starting from NAMEA data. For each pollutant the first row indicates the emissions generated directly from Italian households, while the second row records all indirect emissions caused by industries to produce the final demand.

Table 2
Total output of the Italian economy (1999–2006) (M€ at prices of 1999).

	1999	2006	Variation % (1999–2006)
Agriculture, hunting and forestry	34,433	34,689	0.7
Fishing	1911	1836	−3.9
Mining	10,293	10,416	1.2
Food and beverages	79,089	86,576	9.5
Textile and clothing	57,649	57,728	0.1
Other manufacturing	33,469	35,172	5.1
Paper and graphics	26,701	28,702	7.5
Chemistry and petrochemical	51,791	46,416	−10.4
Building materials, glass and ceramic	8176	9129	11.7
Metallurgy	26,291	25,655	−2.4
Mechanics	62,591	71,014	13.5
Construction	17,758	18,797	5.9
Electricity, gas and vapour	26,166	30,354	16.0
Tertiary	616,356	688,340	11.7
Public Administration	1164	1027	−11.7
Road transports	43,431	50,719	16.8
Sea freights	1502	1301	−13.4
Air transports	6849	6456	−5.7

6 Imported products are assumed to be produced in the same way as the products in the Italian industry.

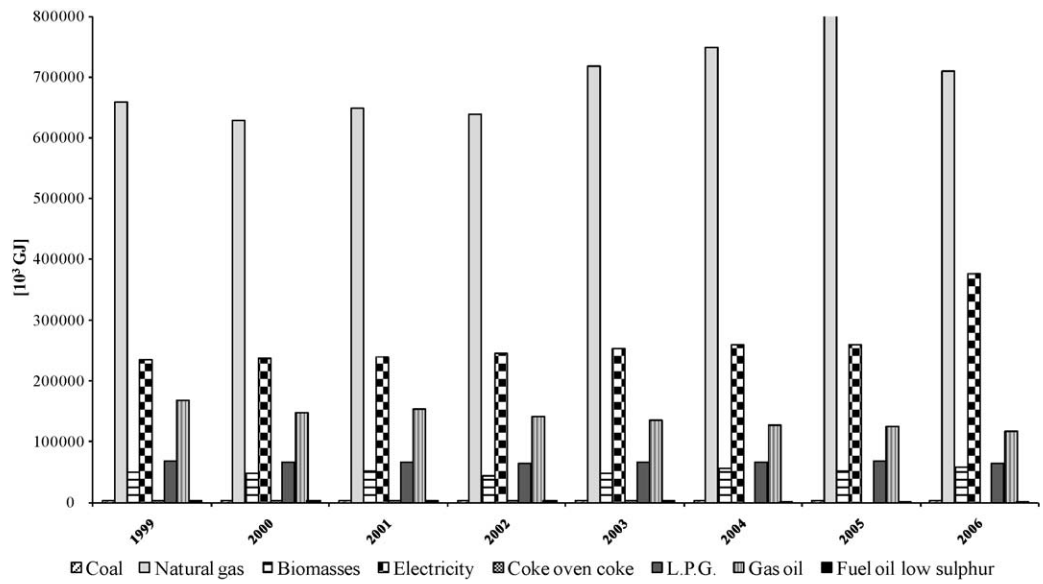

Fig. 3. Trend of direct energy consumptions.

Table 3
Trend of specific energy consumptions (direct, indirect and total).

Year	Population [inhabitants]	Direct energy [MJ/inhabitants]	Indirect energy [MJ/inhabitants]	Total energy [MJ/inhabitants]
1999	56,909,109	20,842	63,670	84,512
2000	56,923,524	19,904	64,374	84,278
2001	56,960,692	20,432	64,544	84,976
2002	56,993,742	19,934	64,942	84,876
2003	57,321,070	21,371	67,496	88,867
2004	57,888,245	21,760	66,774	88,534
2005	58,462,375	22,544	66,875	89,420
2006	58,751,711	22,601	65,830	88,432

Indirect emissions are the main source of pollutants, in particular for N_2O (about 91%), CH_4 (about 97%), SO_x (about 95%) and NH_3 (about 96%). The households activities (direct emissions) generate mostly NMVOC (about 70%) and CO (about 80%).

It can be observed that in the examined period the pollutant emissions have a variable trend. Comparing the years 1999 and 2006, the emissions decrease for all pollutants, except for $CO_{2fossil}$, which increases of 4.5%, and N_2O, which increases of 0.07%. A significant decrease is associated to SO_2 (−154%), CO (−59%), NMVOC (−45%) and NO_x (−41%).

It can be highlighted that the main contribution to CO_2 emissions comes from tertiary (21–22%) and from "electricity, gas and vapour" (15–16%). The incidence of the sectors "food and beverage", "chemistry and petrochemical", and road transports is variable from 3% to 6% of the total. The contribution of the other sectors on the total emissions accounts for less than 2.5%.

The economic sectors with the highest specific emissions (per million of euro) are "electricity, gas and vapour", sea freights and "building materials, glass and ceramic". Those ones with the lowest specific emissions are constructions, tertiary, public administration, mechanics and other manufacturing.

Table 4
Indirect energy consumption for different economic sectors (1999–2006) (10^6 GJ).

	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture, hunting and forestry	42.5	45.1	47.4	49.2	48.8	50.2	54.3	53.5
Fishing	11.0	10.3	11.5	11.7	12.1	13.0	13.3	12.6
Mining	2.0E−02	1.8E−02	2.2E−02	1.7E−02	1.8E−02	3.1E−02	3.2E−02	2.4E−02
Food and beverages	307	309	316	327	341	335	3428	336
Textile and clothing	189	183	190	191	196	185	181	176
Other manufacturing	86.7	82.5	81.6	84.2	87.9	87.2	86.7	85.7
Paper and graphics	70.2	71.8	69.8	69.3	74.0	70.4	71.8	70.2
Chemistry and petrochemical	253	237	242	226	241	235	242	215
Building materials, glass and ceramic	27.4	29.3	28.6	29.5	30.2	28.6	29.2	27.5
Metallurgy	11.8	10.7	10.1	9.0	10.1	9.4	9.0	8.3
Mechanics	145	148	147	141	145	147	147	146
Construction	28.6	29.5	28.0	26.6	27.0	26.1	25.7	26.4
Electricity, gas and vapour	675	710	682	722	750	765	775	742
Tertiary	1106	1130	1145	1139	1204	1196	1223	1244
Public Administration	3.0	2.6	2.7	2.5	2.7	2.4	2.4	2.7
Road transports	606	598	610	606	621	626	613	621
Sea freights	5.0	4.5	4.9	4.8	4.9	5.4	5.1	4.7
Air transports	58.5	61.6	60.5	61.9	73.0	84.1	89.3	95.1

Table 5
Indirect energy consumption for different energy sources (1999–2006) (10^6 GJ).

	1999	2000	2001	2002	2003	2004	2005	2006
Coal	161	181	207	234	258	310	306	292
Brown coal	0.31	0.10	0.04	0.03	0.03	0.02	0.02	0.02
Natural gas	951	1008	991	987	1104	1143	1236	1236
Biomass	11	14	18	25	38	42	47	43
Electricity	431	445	453	457	479	480	489	492
Coke oven coke	36	30	33	28	30	28	28	26
Coke oven gas	9.7	10.4	8.3	8.2	8.9	8.6	8.2	9.2
Products derived from gas	0.1	0.1	0	0	0	0	0	0
Blast-furnace gas	24	23	20	21	21	21	25	25
L.P.G.	67	66	66	62	60	56	55	50
Residual gas from refining	87	81	71	72	76	77	84	80
Light distilled petrol	2.0	2.8	8.0	7.4	6.2	1.8	1.5	0.7
Gasoline	476	448	451	431	416	391	364	341
Jet kerosene	107	111	106	105	122	124	131	136
Petroleum	2.0	1.4	3.0	1.6	1.3	0.8	0.5	0.5
Gas oil	558	580	610	624	663	693	711	725
High sulphur fuel oil	253	225	250	215	135	110	84	80
Low sulphur fuel oi	393	384	324	370	399	324	278	274
Petroleum coke	52	54	54	50	48	53	60	54
Non energetic petroleum products	1.8	1.2	1.1	1.7	1.7	1.2	1.2	3.8

The N_2O emissions are mainly caused by "food and beverage" (27–30% of the total), tertiary (25–26% of the total), and "agriculture, hunting and forestry" (17–21% of the total). The contributions of "textile and clothing" and "chemistry and petrochemical" sectors vary from 3% to 11%. The other sectors contribute for less than 2%.

The sectors of "agriculture, hunting and forestry", "chemistry and petrochemical", and "building materials, glass and ceramic" involve the highest specific emissions, while the lowest specific impacts arise from the sectors of public administration, mechanics, constructions and other manufacturing.

With regard to the emissions of CH_4, the tertiary sector accounts for 42–45%, followed by the sectors of "food and beverage" (21–22%) and "agriculture, hunting and forestry" (11–14%). A contribution variable from 2% to 7% is given by "textile and clothing", "chemistry and petrochemical", and "electricity, gas and vapour". The highest specific emissions are related to "agriculture, hunting and forestry", mining and "electricity, gas and vapour", while the lowest are due to public administration, mechanics, constructions and other manufacturing.

With regard to the NO_x emissions the tertiary sector accounts for the 22–27%, followed by the sectors of "electricity, gas and vapour" and road transports, each one sharing for 5–8% on the total emissions. A contribution lower than 3% arises from the other sectors. The road transports and mechanics sectors involve the highest and the lowest specific emissions, respectively.

The main contribution to the SO_x emissions comes from the sectors of "electricity, gas and vapour" (21–31%), tertiary (24–25%) and "chemistry and petrochemical" (13–20%). A contribution variable from 2% to 6% arises from the sectors of "food and beverage", "textile and clothing", other manufacturing, mechanics, road transports and sea freights. The highest specific emissions come from sea freights and "electricity, gas and vapour", while the lowest comes from the tertiary and construction.

The most contributing sectors to the NH_3 emissions are: "food and beverage" (39–41%), "agriculture, hunting and forestry" (25–29%), tertiary (20–23%) and "textile and clothing" (3–4%). An incidence lower than 1% comes from the other sectors. "Agriculture, hunting and forestry" is responsible of the highest specific emissions. Very low specific emissions are related to the other sectors.

Regarding to the NMVOC emissions, the tertiary accounts for 10–11%. A contribution variable from 1% to 5% is due to "food and beverage", "textile and clothing", other manufacturing, "chemistry and petrochemical", mechanics, "electricity, gas and vapour", and

Table 6
Indirect energy consumption per unit of output (10^6 MJ/M€).

	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture, hunting and sylviculture	1.24	1.32	1.38	1.44	1.48	1.43	1.53	1.54
Fishing	5.76	5.01	6.18	6.38	6.38	6.95	7.40	6.87
Mining	2.0E−03	1.8E−03	2.1E−03	1.7E−03	1.8E−03	3.0E−03	3.0E−03	2.3E−03
Food and Beverages	3.89	3.71	3.89	4.01	4.12	4.01	3.97	3.88
Textile and clothing	3.24	3.13	3.16	3.12	3.22	3.15	3.12	3.05
Other manufacturing	2.59	2.44	2.44	2.41	2.51	2.42	2.45	2.44
Paper and graphics	2.63	2.60	2.45	2.53	2.62	2.46	2.49	2.44
Chemistry and petrochemical	4.88	4.83	5.05	4.65	4.86	4.73	5.04	4.63
Building materials, glass and ceramic	3.35	3.43	3.10	3.09	3.19	3.08	3.10	3.02
Metallurgy	0.45	0.42	0.38	0.34	0.37	0.36	0.35	0.32
Mechanics	2.31	2.27	2.24	2.22	2.20	2.14	2.11	2.06
Construction	1.61	1.67	1.49	1.47	1.49	1.48	1.40	1.40
Electricity, gas and vapor	25.8	27.7	26.0	26.6	26.4	25.8	25.3	24.4
Tertiary	1.79	1.76	1.75	1.73	1.82	1.79	1.82	1.81
Public Administration	2.56	2.60	2.58	2.63	2.76	2.60	2.62	2.64
Road transports	14.0	13.6	13.7	13.1	13.0	12.6	11.9	12.2
Water transports	3.34	3.03	3.23	2.79	3.00	3.68	3.69	3.64
Air transports	8.54	8.29	8.77	9.24	10.44	14.02	14.37	14.73

Table 7
Direct and indirect air emissions caused by Italian households (1999–2006).

	1999	2000	2001	2002	2003	2004	2005	2006
$CO_{2fossil}$ [tons]								
Direct emissions	1.11E+08	1.05E+08	1.07E+08	1.07E+08	1.12E+08	1.10E+08	1.11E+08	1.04E+08
Indirect emissions	1.97E+08	1.98E+08	2.00E+08	2.02E+08	2.10E+08	2.10E+08	2.12E+08	2.08E+08
Total	3.08E+08	3.04E+08	3.07E+08	3.09E+08	3.22E+08	3.21E+08	3.22E+08	3.12E+08
N_2O [tons]								
Direct emissions	7.22E+03	7.23E+03	7.62E+03	8.14E+03	8.60E+03	8.76E+03	8.50E+03	8.41E+03
Indirect emissions	8.69E+04	8.76E+04	8.78E+04	8.64E+04	8.66E+04	8.65E+04	8.57E+04	7.50E+04
Total	9.41E+04	9.48E+04	9.54E+04	9.46E+04	9.53E+04	9.53E+04	9.42E+04	8.34E+04
CH_4 [tons]								
Direct emissions	5.43E+04	5.00E+04	4.56E+04	4.16E+04	4.24E+04	4.75E+04	4.41E+04	4.34E+04
Indirect emissions	1.44E+06	1.43E+06	1.39E+06	1.35E+06	1.34E+06	1.27E+06	1.28E+06	1.23E+06
Total	1.49E+06	1.48E+06	1.43E+06	1.39E+06	1.38E+06	1.32E+06	1.33E+06	1.27E+06
NO_x [tons]								
Direct emissions	4.02E+05	3.43E+05	3.28E+05	2.82E+05	2.81E+05	2.49E+05	2.19E+05	1.84E+05
Indirect emissions	6.02E+05	5.78E+05	5.72E+05	5.50E+05	5.49E+05	5.16E+05	4.92E+05	4.74E+05
Total	1.00E+06	9.20E+05	9.00E+05	8.32E+05	8.30E+05	7.65E+05	7.11E+05	6.58E+05
SO_x [tons]								
Direct emissions	3.17E+04	1.87E+04	1.95E+04	1.64E+04	1.60E+04	1.50E+04	1.30E+04	1.14E+04
Indirect emissions	5.16E+05	4.19E+05	3.83E+05	3.44E+05	2.85E+05	2.57E+05	2.02E+05	1.88E+05
Total	5.48E+05	4.38E+05	4.02E+05	3.60E+05	3.02E+05	2.72E+05	2.15E+05	1.99E+05
NH_3 [tons]								
Direct emissions	1.23E+04	1.33E+04	1.44E+04	1.60E+04	1.57E+04	1.58E+04	1.51E+04	1.48E+04
Indirect emissions	3.35E+05	3.29E+05	3.33E+05	3.28E+05	3.28E+05	3.12E+05	3.15E+05	3.12E+05
Total	3.47E+05	3.43E+05	3.48E+05	3.44E+05	3.44E+05	3.27E+05	3.30E+05	3.27E+05
NMVOC [tons]								
Direct emissions	9.54E+05	8.09E+05	7.56E+05	6.95E+05	6.95E+05	6.64E+05	6.23E+05	5.83E+05
Indirect emissions	3.76E+05	3.45E+05	3.33E+05	3.17E+05	2.97E+05	2.94E+05	2.93E+05	2.89E+05
Total	1.33E+06	1.15E+06	1.09E+06	1.01E+06	9.92E+05	9.59E+05	9.17E+05	8.72E+05
CO [tons]								
Direct emissions	4.13E+06	3.52E+06	3.50E+06	3.14E+06	3.15E+06	2.92E+06	2.53E+06	2.32E+06
Indirect emissions	8.80E+05	8.06E+05	7.94E+05	6.72E+05	6.14E+05	6.40E+05	6.25E+05	6.07E+05
Total	5.01E+06	4.33E+06	4.29E+06	3.81E+06	3.76E+06	3.56E+06	3.16E+06	2.93E+06
PM10 [tons]								
Direct emissions	3.59E+04	3.34E+04	3.39E+04	3.02E+04	3.13E+04	3.34E+04	3.15E+04	3.26E+04
Indirect emissions	9.65E+04	9.04E+04	9.04E+04	8.59E+04	8.28E+04	8.00E+04	7.49E+04	7.11E+04
Total	1.32E+05	1.24E+05	1.24E+05	1.16E+05	1.14E+05	1.13E+05	1.06E+05	1.04E+05

Table 8
Total air emissions caused by Italian households (1999–2006): a comparison among three scenarios.

	1999	2000	2001	2002	2003	2004	2005	2006
$CO_{2fossil}$ [tons]								
Scenario 1	3.08E+08	3.04E+08	3.07E+08	3.09E+08	3.22E+08	3.21E+08	3.22E+08	3.12E+08
Scenario 2	4.04E+08	4.06E+08	4.09E+08	4.12E+08	4.31E+08	4.32E+08	4.38E+08	4.17E+08
Scenario 3	2.72E+08	2.74E+08	2.76E+08	2.78E+08	2.92E+08	2.95E+08	3.00E+08	2.94E+08
N_2O [tons]								
Scenario 1	9.41E+04	9.48E+04	9.54E+04	9.46E+04	9.53E+04	9.53E+04	9.42E+04	8.34E+04
Scenario 2	8.37E+03	8.39E+03	8.56E+03	8.58E+03	8.82E+03	8.86E+03	8.88E+03	9.23E+03
Scenario 3	4.79E+03	4.86E+03	4.95E+03	5.01E+03	5.23E+03	5.29E+03	5.32E+03	5.33E+03
CH_4 [tons]								
Scenario 1	1.49E+06	1.48E+06	1.43E+06	1.39E+06	1.38E+06	1.32E+06	1.33E+06	1.27E+06
Scenario 2	5.20E+05	5.34E+05	5.41E+05	5.48E+05	5.83E+05	6.00E+05	6.15E+05	5.80E+05
Scenario 3	1.25E+05	1.28E+05	1.30E+05	1.32E+05	1.38E+05	1.39E+05	1.41E+05	1.42E+05
NO_x [tons]								
Scenario 1	1.00E+06	9.20E+05	9.00E+05	8.32E+05	8.30E+05	7.65E+05	7.11E+05	6.58E+05
Scenario 2	6.92E+05	6.99E+05	7.14E+05	7.20E+05	7.50E+05	7.61E+05	7.67E+05	7.51E+05
Scenario 3	3.22E+05	3.27E+05	3.37E+05	3.42E+05	3.54E+05	3.62E+05	3.63E+05	3.61E+05
SO_x [tons]								
Scenario 1	5.48E+05	4.38E+05	4.02E+05	3.60E+05	3.02E+05	2.72E+05	2.15E+05	1.99E+05
Scenario 2	8.49E+05	8.50E+05	8.74E+05	8.76E+05	8.78E+05	8.86E+05	8.77E+05	8.82E+05
Scenario 3	5.76E+05	5.80E+05	6.05E+05	6.07E+05	6.04E+05	6.21E+05	6.15E+05	6.07E+05
NH_3 [tons]								
Scenario 1	3.47E+05	3.43E+05	3.48E+05	3.44E+05	3.44E+05	3.27E+05	3.30E+05	3.27E+05
Scenario 2	8.50E+03	8.26E+03	8.33E+03	8.20E+03	8.24E+03	8.04E+03	7.90E+03	7.38E+03
Scenario 3	2.57E+02	2.56E+02	2.62E+02	2.67E+02	3.01E+02	3.10E+02	3.05E+02	3.05E+02
CO [tons]								
Scenario 1	5.01E+06	4.33E+06	4.29E+06	3.81E+06	3.76E+06	3.56E+06	3.16E+06	2.93E+06
Scenario 2	1.25E+06	1.18E+06	1.19E+06	1.13E+06	1.15E+06	1.11E+06	1.11E+06	9.20E+05
Scenario 3	4.29E+05	3.97E+05	3.99E+05	3.65E+05	3.90E+05	3.88E+05	4.02E+05	3.97E+05

Table 9
Environmental impacts caused by Italian households (1999–2006): a comparison among three scenarios.

	1999	2000	2001	2002	2003	2004	2005	2006
GWP [kg CO_{2eq}]								
Scenario 1	3.78E+11	3.72E+11	3.75E+11	3.75E+11	3.88E+11	3.85E+11	3.86E+11	3.71E+11
Scenario 2	4.20E+11	4.22E+11	4.26E+11	4.29E+11	4.48E+11	4.51E+11	4.57E+11	4.34E+11
Scenario 3	2.77E+11	2.79E+11	2.81E+11	2.83E+11	2.98E+11	3.00E+11	3.05E+11	2.98E+11
POCP [kg C_2H_{4eq}]								
Scenario 1	1.70E+08	1.47E+08	1.44E+08	1.29E+08	1.24E+08	1.17E+08	1.04E+08	9.63E+07
Scenario 2	9.70E+07	9.55E+07	9.73E+07	9.60E+07	9.76E+07	9.75E+07	9.72E+07	9.17E+07
Scenario 3	4.90E+07	4.85E+07	5.00E+07	4.93E+07	5.03E+07	5.12E+07	5.14E+07	5.06E+07
AP [kg SO_{2eq}]								
Scenario 1	1.71E+09	1.53E+09	1.49E+09	1.40E+09	1.33E+09	1.23E+09	1.14E+09	1.09E+09
Scenario 2	1.38E+09	1.38E+09	1.42E+09	1.42E+09	1.44E+09	1.46E+09	1.45E+09	1.45E+09
Scenario 3	8.53E+08	8.60E+08	8.95E+08	8.99E+08	9.03E+08	9.27E+08	9.20E+08	9.07E+08
EP [kg $PO_4{}^{3-}{}_{eq}$]								
Scenario 1	2.52E+08	2.40E+08	2.39E+08	2.28E+08	2.28E+08	2.14E+08	2.08E+08	2.00E+08
Scenario 2	9.29E+07	9.37E+07	9.58E+07	9.65E+07	1.00E+08	1.02E+08	1.02E+08	1.00E+08
Scenario 3	4.20E+07	4.26E+07	4.39E+07	4.45E+07	4.61E+07	4.72E+07	4.72E+07	4.67E+07

road transports. The other sectors amount to less than 1%. The sea freights sector is characterized by the highest specific emissions, while the lowest specific emissions arise from public administration, tertiary and “building materials, glass and ceramic”.

The CO emissions are mainly caused by tertiary (5–7%), “food and beverage” (3–5%) and “agriculture, hunting and forestry” (2–3%). The other sectors contribute for less than 1%. Sea freights, “agriculture, hunting and forestry”, and metallurgy involve the highest specific emissions, while “food and beverage”, “paper and graphics”, and construction involve the lowest ones. The main contribution to the PM10 emissions comes from tertiary sector (22–25%), followed by “food and beverage” (15–16%), “agriculture, hunting and forestry” (7–10%), road transports (5%), “electricity, gas and vapour” (2–5%), and “textile and clothing” (2–3%). Other sectors give a negligible contribution (<2%). Road transports and “agriculture, hunting and forestry” are characterized by the highest specific emissions. The sectors of mechanics and “paper and graphics” give the lowest specific emissions.

Looking at the trend of specific emissions, all them decrease. In particular the lowest rate of reduction occurs for CO_2 (2%), while the highest one for SO_x (53%). For the other specific emissions the reduction rate falls within 5–25%.

In Tables 8 and 9 seven pollutant emissions ($CO_{2fossil}$, N_2O, CH_4, NO_x, SO_x, NH_3 and CO) and the related potential environmental impacts (Global Warming Potential – GWP, Photochemical Oxidation – POCP, Acidification Potential – AP, Eutrophication Potential – EP), obtained by means of the three different Eqs. (8)–(10) are shown. In detail, the following three scenarios are assumed:

- Scenario 1: use of NAMEA data (Table 7);
- Scenario 2: use of emission factors related to the life cycle of different energy sources, including the impacts due to the supplying phase, use of energy and end-of-life.
- Scenario 3: use of emission factors related to the use phase of energy sources (such as emissions from fuel combustion).

Scenario 1, which also includes the emissions from non-energy sources (for example during the productive processes), involves the highest emissions, except for $CO_{2fossil}$ and SO_x. In Scenarios 2 and 3 the emissions are referred only to the energy use. Consequently, the environmental impacts are highest in the Scenario 1, except for the GWP.

With regard to GWP, it can be noted that it has the same order of magnitude for all the three scenarios. This does not occur for the other assessed impacts.

The results of the comparison of the above scenarios highlight the necessity to use NAMEA data as much as possible in order to obtain reliable information on the assessment of environmental impact.

From a comparison between Scenarios 2 and 3, air emissions and environmental impacts result higher in Scenario 2, even of an order of magnitude. Thus the environmental impacts caused by the energy use should be assessed by means a life-cycle approach, including the indirect emissions related to the supplying and/or transformation of the energy sources.

5. Conclusion

The energy and environmental IOA is able to simulate the structure of an economy and to provide a useful framework for tracing energy use and environmental impacts associated with inter-industry activities and the final consumptions.

This paper proposed a model that combines the energy and EEIO analysis with LCA, and that can be applied to evaluate the energy and environmental impacts related to the “life-cycle” of a whole economy.

The model presents some limitations, related to the use of data that can be influenced by errors and sources of uncertainty and to the assumptions of constant technical coefficients, linearity of production function and linear correlation between monetary production and energy consumption or pollutant emissions. However, it has the advantage to be easy to apply, and based on the elaboration of data regularly published by public sources.

The model was applied to assess the trend, over time, of energy consumptions, air emissions and environmental impacts related to the Italian households consumption in the period 1999–2006 and to identify the economic activities characterized by the greatest impacts.

The final results showed that the examined period was characterized by an increase of the consumption of goods and services with a consequent increase of the direct and indirect energy consumptions. In detail, the indirect energy use accounts for 75% of the total one and mainly comes from the sectors of tertiary, “electricity, gas and vapour”, and “food and beverage”. The direct energy use (25% of the total) is essentially constituted by electricity, natural gas and gas–oil.

Analysing the air emissions and the related environmental impacts, a reduction of all the examined pollutants and impacts was noted, except for $CO_{2fossil}$ emissions and GWP. Looking at the specific emissions (tons/M€) and the related specific impacts, these decrease in the examined period.

The final results of the study can offer important items to assess the relationships among economic growth, energy consumptions and environmental impacts, and to identify the sectors upon which

it is necessary to intervene in order to improve the environmental performance of an economy.

Finally, the proposed model can represent an original contribution to assess the effectiveness of sustainable production and consumption strategies. It can be used to support the national and local decision-makers in the planning of the environmental policies for reducing energy and environmental impacts caused by final users consumptions.

Appendix A.

Starting from the SUTs at current prices and at prices of the preceding year (for example SUT of the year 2006 at current prices and SUTs of the year 2006 at prices of 2005), provided by ISTAT, a group of indices was estimated to calculate the SUTs at the prices of a base year, that is the 1999.

The generic element of the supply or use table $v_{i,t(t)}$ referred to the year t and expressed at prices of the year t is obtained multiplying the current prices for unit of product i for the total quantity of i produced in the year t:

$$v_{i,t(t)} = p_t q_t \tag{A.1}$$

$v_{i,t(t-1)}$ is the same element expressed at prices of the year $t-1$; it is obtained multiplying the prices for unit of product i valued at prices of the preceding year ($t-1$) and the total quantity of good i produced in the year t:

$$v_{i,t(t-1)} = p_{t-1} q_t \tag{A.2}$$

Dividing $v_{i,t(t-1)}$ and $v_{i,t(t)}$ it is obtained the index $I_{t,t-1}$ that represents the ratio between the prices for the two consecutive years ($t-1$ and t):

$$I_{t,t-1} = \frac{v_{i,t(t-1)}}{v_{i,t(t)}} = \frac{p_{t-1} q_t}{p_t q_t} = \frac{p_{t-1}}{p_t} \tag{A.3}$$

Similarly, $v_{i,t+1(t+1)}$ is the generic element of the supply or use table referred to the year $t+1$ and expressed at prices of the year $t+1$:

$$v_{i,t+1(t+1)} = p_{t+1} q_{t+1} \tag{A.4}$$

and $v_{i,t+1(t)}$ the same element valued at prices of the year t:

$$v_{i,t+1(t)} = p_t q_{t+1} \tag{A.5}$$

Dividing $v_{i,t+1(t)}$ and $v_{i,t+1(t+1)}$ it is obtained the index $I_{t+1,t}$ that represents the ratio between the prices for the two consecutive years (t and $t+1$):

$$I_{t+1,t} = \frac{v_{i,t+1(t)}}{v_{i,t+1(t+1)}} = \frac{p_t q_{t+1}}{p_{t+1} q_{t+1}} = \frac{p_t}{p_{t+1}} \tag{A.6}$$

Combining $I_{t,t-1}$ and $I_{t+1,t}$ it's possible to transform $v_{i,t+1(t+1)}$, expressed at prices of the year $t+1$ in $v_{i,t+1(t-1)}$ expressed at prices of the year $t-1$ using the following equation:

$$v_{i,t+1(t-1)} = v_{i,t+1(t+1)} I_{t+1,t} I_{t,t-1} = \frac{p_{t+1} q_{t+1} p_t}{p_{t+1}} \frac{p_{t-1}}{p_t} = p_{t-1} q_{t+1} \tag{A.7}$$

Applying the above procedure, the SUTs at current prices have been deflated to the base year of 1999.

Starting from these SUTs, the IOTs at prices of 1999 have been calculated for the period 1999–2006.

Table B.1
Inputs for the calculation of IOTs.

Name	Dimension	Description
PROD	59 × 59	Matrix of production. It shows the origin of the resources. It is constituted by the first 59 rows and 59 columns of the supply table
COSTIPB	59 × 59	Matrix of costs. It shows the use of the resources. It is constituted by the first 59 rows and 59 columns of the use table at basic prices
G	1 × 59	Vector of the production per industrial sector. It shows the total resources produced by each sector. It is constituted by the first 59 elements of the row 60 of the supply table
Q	59 × 1	Vector of the production per product. It shows the total resources used to produce each tipology of product. It is constituted by the first 59 elements of the column 60 of the supply table
COSTIIM	59 × 59	Matrix of imported costs. It is constituted by the first 59 rows and 59 columns of the use table of importations

Table B.2
Intermediate matrixes needed for the calculation of IOTs.

Name	Dimension	Description
Diag(G)	59 × 59	Diagonal matrix, where the elements of the diagonal are those of the vector G, while the other elements are zero
Diag(G)$^{-1}$	59 × 59	Inverse matrix of the matrix Diag(G)
PROD$^{\mathrm{T}}$	59 × 59	Transpose matrix of the matrix PROD
Diag(Q)	59 × 59	Diagonal matrix, where the elements of the diagonal are those of the vector Q, while the other elements are zero
Diag(Q)$^{-1}$	59 × 59	Inverse matrix of the matrix Diag(Q)
D = PROD$^{\mathrm{T}}$ × Diag(G)$^{-1}$	59 × 59	Matrix of the market shares. It shows the ratios of the total output of each product produced by each industrial sectors
B_{tot} = COSTIPB × Diag(G)$^{-1}$	59 × 59	Matrix of the total coefficients of products at base prices
B_{imp} = COSTIIM × Diag(G)$^{-1}$	59 × 59	Matrix of the total coefficients of imported products at base prices
$B_{int} = B_{tot} - B_{imp}$	59 × 59	Matrix of the total coefficients of domestic products at base prices
$A_{tot} = B_{tot} \times D$	59 × 59	Matrix of the direct total coefficients at base prices
$A_{imp} = B_{imp} \times D$	59 × 59	Matrix of the direct imported coefficients at base prices
$A_{int} = B_{int} \times D$	59 × 59	Matrix of the direct domestic coefficients at base prices

Table B.3
Calculation of IOTs.

Name	Dimension	Description
SIMM$_{tot}$ = A_{tot} × Diag(Q)	59 × 59	Total input–output matrix (domestic production + imports)
SIMM$_{imp}$ = A_{imp} × Diag(Q)	59 × 59	Input–output matrix of imports
SIMM$_{int}$ = A_{int} × Diag(Q)	59 × 59	Input–output matrix of domestic production

Appendix B.

Starting from the SUTs at prices of 1999, the derivation of "product by product" IOTs was made according to the framework explained in the following. A more detailed description can be found in [37,38].

Table B.1 shows the inputs for the calculation of IOT, obtained from SUTs. These inputs have been used to calculate the intermediate matrixes reported in Table B.2.

Table B.3 describes the operations to derive the intermediate part of the totals, domestics and of importations IOTs.

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